6.0 RESULTS AND CONCLUSIONS

6.1 EXPLANATION OF RECYCLED URANIUM FLOW PATHS

6.1.1 Flow of RU into the Y-12 Complex

RU entered the Y-12 Complex through a number of different pathways. The plant received RU from three primary source sites:

- receipts of 125,161 kg of highly enriched RU as UN solution or U-Al ingots from SRS; this material was processed in the plant's 9212 and/or 9206 facilities,
- receipts of 25,696 kg of highly enriched RU as UN solution or oxide from ICPP; this material was processed in the plant's 9212 and/or 9206 facilities, and
- receipts of 1,502 kg of slightly depleted RU as oxide from Hanford; the assay associated with this material indicates that it was DU (this material is believed to have been disposed of on the Oak Ridge Reservation without any processing in Y-12 Complex facilities).

The Y-12 Complex also received RU from the following secondary sites:

- receipts of 192,836 kg of slightly depleted RU from ORGDP; this material is believed to have been returned to ORGDP and
- receipts of 38,423 kg of RU as slightly depleted fluorination tower ash from PGDP; this material is believed to have been disposed of on the Oak Ridge Reservation or returned to PGDP without any processing in Y-12 Complex facilities.

The highly enriched RU received by the Y-12 Complex is estimated to have contained the following quantities of the RU constituents of concern:

- Pu: 0.051 g
- Np: 3,700 g
- Tc: 14,500 g

6.1.2 Flow of RU out of the Y-12 Complex

RU streams exited the Y-12 Complex via:

- shipments totaling 120,384 kg of highly enriched RU as metal product to SRS,
- shipments totaling 29,614 kg of RU as slightly depleted fluorination tower ash to PGDP (this material was apparently ash that had been shipped from PGDP to the Y-12 Complex and stored at the plant, but not processed), and
- shipments totaling 192,836 kg of slightly depleted RU to ORGDP.

As of March 31, 1999, approximately 13 MT of highly enriched RU remained in the Y-12 Complex inventory.

The estimated mass balance for highly enriched RU, which is of most concern for worker exposure and is the primary focus of this project, is summarized in Table 6.1-1. A discrepancy in the mass balance between receipts and shipments (plus inventory and waste) reflects an inability to precisely distinguish between RU and non-RU shipments and receipts involving the Y-12 Complex and Savannah River. Shipments of fresh fuel (non-RU) and sweetener (also non-RU) were made from the Y-12 Complex to SRS along with RU shipments. The only way to distinguish between these RU and non-RU streams using available records is by enrichment level. Shipments of ≤90% enrichment were assumed to be RU. Shipments of >90% enrichment were assumed to be non-RU fresh fuel or sweetener. This methodology using enrichment level to distinguish between RU and non-RU results in good estimates of RU flows that are reasonably consistent with SRS estimates. Although this is the best available means of distinguishing RU streams, this method does leave a difference of approximately 17.3 MTU between receipts and shipments.

Table 6.1-1 Estimated Mass Balance for Highly Enriched RU

	RU Received (kg U)	RU Shipped (kg U)
Savannah River	125,161	120,384
ICPP	25,696	0
TOTAL	**150,857**	**120,384**
Total RU Shipped		120,384
RU Inventory (as of 3/31/99)		13,082
Estimated RU Waste		~100
TOTAL	**150,857**	**133,566**
Difference*		~17,300

** This difference is due to the inability to precisely distinguish between RU and non-RU shipments.*

Slightly depleted RU streams received by the Y-12 Complex from ORGDP, PGDP, and Hanford are believed to have been returned to the shipping site or disposed of as waste on the Oak Ridge Reservation. No evidence of Y-12 Complex processing of this material was identified in the historical records reviewed by the Project Team.[1]

6.1.3 Flow of RU within the Y-12 Complex

Within the Y-12 Complex, highly enriched RU followed pathways associated with:

- Building 9212 complex processes,
- Building 9206 processes, and
- processes associated with other Y-12 Complex facilities.

The steps associated with each of these pathways are described in the following sections.

[1] Five shipments of slightly enriched RU oxide from SRS totaling about 42.6 MT were received at the Y-12 Complex but immediately transferred to Fernald.

6.1.3.1 Building 9212 Complex Processes

Building 9212 complex processes involved the following pathways:

- receiving UN solution from ICPP (in safe bottles) or from SRS (in tanker trucks)
- weighing SRS tanker trucks (at Building 9929-1)
- sampling UN solution
- pouring UN solution from ICPP safe bottles into "pour-up" stations for transfer to intermediate storage tanks
- pumping UN solution from SRS tanker trucks to 9212
- evaporating and concentrating UN
- manual filling and loading of UN into safe bottles for transfer to 9206 (in the period after 9206 assumed responsibility for certain recovery operations from 9212)
- ICPP UO_3 received and dissolved to produce UN (in the period after ICPP began sending UO_3 instead of UN)
- purification of UN via solvent extraction (primary and secondary extraction)
- pumping of solvent extraction raffinate to S-3 Ponds
- feeding of solvent extraction raffinate to 9212 bioreactor
- transporting of solvent extraction raffinate to WETF
- denitration of UNH to UO_3
- maintenance on denitrator or fluid beds
- conversion of UO_3 to UF_4 in converted lab muffle furnaces
- removal of dry UF_4 from process
- "bomb" reduction of UF_4 to uranium metal
- sampling, fracturing, and packaging of uranium metal buttons
- salvage operations for U-Al from SRS
- metal product shipped from Building 9720-5

6.1.3.2 Building 9206 Processes

Building 9206 processes involved the following pathways:

- UN solution "poured-up" into safe tanks
- U-Al ingots received from SRS at Building 9720-5
- dross and sweepings received
- U-Al ingots (or dross/sweepings) dissolved in NaOH to remove Al; sodium diuranate produced
- sodium diuranate dissolved in nitric acid to produce UN
- UO_3 received and dissolved to form UN
- purification of UN via solvent extraction (primary and secondary extraction)
- isolation and transport of raffinate to 9212
- denitration of UNH to UO_3
- maintenance on denitrator or fluid beds
- conversion of UO_3 to UF_4

- removal of dry UF_4 from process
- "bomb" reduction of UF_4 to uranium metal

6.1.3.3 Processes Associated with Other Y-12 Complex Facilities

- capping and closure of S-3 Ponds and sludge removal and closure of New Hope Pond
- treatment of nitrate waste at WETF
- storage of RU materials at Building 9720-5

6.2 EVALUATION OF ACTIVITIES THAT INVOLVED POTENTIAL WORKER EXPOSURE TO RU CONSTITUENTS

Prior to and during the processing of RU, the Y-12 Complex also operated as a uranium-processing facility. Careful consideration for worker protection was given to the introduction of RU for processing. A criterion for acceptance was based upon DOE/OR-859[2] which in turn, was derived from an informal agreement between the Y-12 Complex and SRS. The intent of this criterion was to maintain the relative hazard potential of all non-uranium alpha emitters to less than 7% of the relative hazard potential of uranium.[3] With this limitation, it was expected that RU could be safely managed by the measures already in place for processing uranium.

The Project Team carefully analyzed and evaluated 36 activities identified as involving potential for worker exposure. The team assigned the following Occupational Exposure Potential (OEP) scores:

- No Significant OEP 8 activities
- Low OEP 1 activity
- Moderate OEP 27 activities

Available analytical data showed that the majority of the RU constituents of concern tended to follow the HEU through the chemical processes in Buildings 9212 and 9206. Consequently, a majority of the RU constituents ended up in the HEU metal buttons shipped to SRS, while some concentration of RU constituents (relative to the uranium flow) occurred in the various solvent extraction raffinate streams. However, dose calculations using the prescribed DOE methodology indicate that the fractional contribution of the RU constituents for most process streams generally was greater than 50%. Consequently, for most exposure scenarios identified in Table 2.6, a value of 3 was assigned for the constituent level. The reader should note that the TRU-element and fission-product concentrations alone were not sufficiently high for any of the exposure scenarios to warrant this highest constituent rating of 3. Instead, the assignment of a constituent level of 3 was driven largely by the unusually high concentrations of ^{236}U in the SRS RU. On the other hand, ICPP RU had an average ^{236}U content of <10%. Activities involving only ICPP RU thus received a constituent level rating of 2.

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[2] Egli et al., *The Report of the Joint Task Force on Uranium Recycle Materials Processing*, 1985.
[3] Vath and Duerksen, *Criteria for Acceptance and Technical Assessment for Acceptance of Enriched Uranium at the Y-12 Plant*, April 25, 1996.

Airborne potential values associated with the various exposure scenarios ranged from 0 to 3. The lowest airborne rating was assigned to HEU operations in which there was virtually no potential for direct worker contact with RU. A value of 1 was assigned to HEU operations involving direct exposure to metal or consolidated solids. A value of 2 was assigned for activities involving exposure to liquid solutions that might spray or evaporate to dryness outside the equipment. A value of 3 was assigned to operations involving direct contact with finely divided RU solids. Duration exposure values were based on actual contact time with RU as defined by DOE.

Most of the potential exposure activities at the Y-12 Complex were found to have a "Moderate" OEP rating as a result of the combined product of a constituent level value of 3 with a value of 1 or 2 for airborne potential and exposure duration. Certain maintenance activities involving equipment that contained finely divided RU solids were assigned a value of 3 for airborne potential. However, because these types of maintenance activities were not performed very often, the overall OEP was rated "Moderate," with a cumulative score of 9.

In no instance did any identified activity involve a combination of airborne potential, constituent level, and exposure duration that produced an OEP score in the "High" range.

6.3 IDENTIFICATION AND EVALUATION OF PROCESSES OR FACILITIES THAT INVOLVED POTENTIAL ENVIRONMENTAL RELEASES

Solvent raffinate streams from Buildings 9212 and 9206 extraction systems—as well as condensed acid streams from the various UN solution evaporators and denitrators—were ultimately discharged to the unlined S-3 Ponds. Chemical analysis of the S-3 Pond sludge indicated the presence of 3,140 g of Tc, 145 g of Np, and <0.01 g of Pu. The S-3 Ponds were capped in 1986, with the sludge left in place under EPA oversight. Uranium has been detected in groundwater monitoring wells around the S-3 Ponds. Therefore, one can infer that RU constituents also leached to the nearby environment from the S-3 Ponds. Data from other locations, such as the WETF and New Hope Pond, were analyzed and determined to have no significant potential for environmental releases.

6.4 DISCUSSION OF DATA SOURCES

To identify and retrieve data, the Project Team searched the Y-12 Complex Records Center and a variety of other data collections at theY-12 Complex, including electronic systems and administrative files. Major data sources consulted and analyzed included:

- NMC&A data, including shipping, receiving, and inventory records (e.g., individual form 101 and 741 Nuclear Material Transfer Reports),
- Y-12 Complex historical site reports on shipments and receipts,
- Y-12 Complex reports describing facilities and production processes,
- Y-12 Complex health physics records,
- Y-12 Complex production records,
- Y-12 Complex analytical laboratory records,
- Y-12 Complex internal correspondence reports,
- correspondence between shippers and receivers,

- historical DOE and contractor reports,
- more recent (i.e., post-1995) health physics reports on the site,
- more recent (i.e., post-1995) environmental survey reports on the site, and
- interviews with Y-12 Complex personnel with direct experience in RU operations.

For incoming and outgoing shipments that lacked sufficient analytical data to ascertain RU constituent flows, the Project Team developed estimates for quantities of RU and/or constituents. These estimates were based on extrapolations from actual data and represent (1) application of known data from similar material and/or circumstances or (2) application of known data from a specific time period over a longer or a shorter period of time. All such estimates and their bases are specifically identified in this report.

This report has been developed to identify and address the significant sources and quantities of RU at the Y-12 Complex from the standpoint of potential worker exposure or environmental consequences. The RU identified as having been received, processed, or shipped by the Y-12 Complex reflects the classical definition of RU as uranium that has been irradiated in reactors and subsequently processed to recover uranium for recycle. Other DOE sites have labeled all material shipped or received during certain periods or from certain facilities as RU. As a result, there exist some discrepancies among sites regarding quantities of RU shipments and receipts that may need to be resolved.

6.5 CONCLUSIONS

6.5.1 Potential Personnel Exposure

Although the Project Team identified 36 activities as having potential for worker exposure, in no instance did any identified activity produce an OEP score in the "High" range. As a result, the potential for worker exposure to TRU elements and fission products at the Y-12 Complex is considered low to moderate.

Early in its existence, the Y-12 Complex implemented a worker protection program that included worker radiological protection (see Section 2.7). This program incorporated such elements as personnel protective equipment, personnel monitoring, environmental monitoring, work location surveys, work-time limits on jobs with penetrating radiation, excretion rate limits, periodic examinations of personnel, and Plant Action Level limits. The inhalation of radioactive materials was recognized as the most important source of possible exposure at the Y-12 Complex. Consequently, administrative controls were primarily designed to guard against associated hazards.

Worker protection measures in place at the Y-12 Complex likely provided substantial mitigation to the risks introduced by the activities rated as moderate to low in OEP. However, dose assessment studies may be warranted as a follow-on activity to provide a more detailed assessment of worker exposure.

6.5.2 Potential Environmental Release

Soil and groundwater around the Y-12 Complex are contaminated with various radionuclides as a direct result of the nature of the Y-12 Complex work and past disposal practices. However, the quantities of RU constituents in and around the plant are very small

and pose no threat to the immediate environment or the surrounding communities. A clear understanding of the nature and extent of the contamination exists, and ongoing environmental programs continue to verify this conclusion. The report of the joint task force assembled by DOE in 1985 to study past and (then) current practices related to the processing of RU reflected similar conclusions.[4] The task force did not find any instance at the Y-12 Complex in which the environment was jeopardized or compromised.

An Oak Ridge Dose Reconstruction Project was initiated in 1994 as follow-up to the Oak Ridge Dose Reconstruction Feasibility Study, which recommended a closer examination of past uranium emissions and potential resulting exposures (see Section 2.8). The Task 6 component of the project involved further evaluation of Oak Ridge uranium operations and effluent monitoring records to determine if uranium releases from the ORR likely resulted in off-site doses that warranted further study. The results were documented in the July 1999 Task 6 report.[5] The Task 6 team concluded that earlier estimates of uranium releases had been underestimated. However, based on the decision guidelines from ORHASP, the Task 6 team concluded that while Y-12 Complex uranium releases are candidates for further study, they are not high-priority candidates.

The Task 7 component of the project involved performing qualitative and quantitative screening of various materials of concern at the Y-12 Complex and the other DOE Oak Ridge sites. Materials screened included Np and Tc. Results were reported in the Task 7 report.[6] Based on the analysis of data, the Task 7 team determined that Np did not warrant further study. Although Tc was identified as one of the potential candidates for further study, it was not determined to be a high-priority candidate.

These analyses, along with other information on environmental consequences from Y-12 Complex operations, identify candidate environmental issues for additional study. However, candidate issues related to the processing of RU have not been determined to be high-priority candidates for further study.

[4] Egli et al., *Report of the Joint Task Force on Uranium Recycle Materials Processing,* 1985.
[5] Buddenbaum, John E., et al. *Uranium Releases from the Oak Ridge Reservation- A Review of the Quality of Historical Effluent Monitoring Data and a Screening Evaluation of Potential Off-Site Exposures,* 1999.
[6] Bruce, Gretchen M. *Screening-Level Evaluation of Additional Potential Materials of Concern,* 1999.

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